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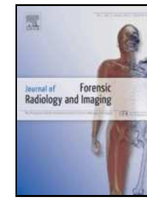

Explanation for the contradiction between the results of Diallo et al. *(doi:10.1016/j.jofri.2018.10.001)* and Winklhofer et al. *(doi:10.1097/RLI.0000000000000032)* in differentiating ferromagnetic from nonferromagnetic bullets by means of the dual-energy index

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With interest, we read the article “Is dual-energy computed tomography helpful to determinate the ferromagnetic property of bullets?” by Diallo et al. [1]. The authors investigated different bullets ($n = 12$) using a polymer phantom and assessed the reproducibility of a study by Winklhofer et al. [2], who investigated bullets ($n = 25$) using an anthropomorphic chest phantom. Computed tomography (CT) scans of the bullets were performed by Diallo et al. and Winklhofer et al. with 100 kVp and 140 kVp, respectively. In both studies, circular region of interest (ROI) measurements were performed in the center of the bullets. The dual-energy index (DEI) was calculated based on mean CT numbers (in Hounsfield units [HU]) obtained from the ROI measurements on both datasets with different kVp settings. The datasets were reconstructed on an extended CT scale to enable measurements beyond the standard range of HU values [3]. Both studies compared the DEIs from ferromagnetic bullets with the DEIs from nonferromagnetic bullets. Diallo et al. [1] presented overall lower DEIs for ferromagnetic bullets than for nonferromagnetic bullets, while Winklhofer et al. [2] yielded overall lower DEIs for nonferromagnetic bullets than for ferromagnetic bullets. Diallo et al. [1] thus revealed an inconsistency concerning the DEI-based differentiation between ferromagnetic and nonferromagnetic bullets, which should be considered for further research on this topic. In this letter, we present the most obvious explanation for the contradiction in their results supported by the results of our own recently published study [BLINDED].

Using the same CT protocol as Diallo et al. [1] and Winklhofer et al. [2], we investigated the X-ray attenuation characteristics of different bullets ($n = 16$) with regard to their metallic components [BLINDED]. As in the study from Diallo et al. [1], we yielded overall low DEIs for the ferromagnetic group compared to the nonferromagnetic group. Our ferromagnetic group consisted of lead bullets with steel jackets, while our nonferromagnetic group consisted of half lead bullets with copper/zinc jackets and half solid copper/zinc bullets. Further investigations revealed that the difference between these two groups was not caused by the presence or absence of ferromagnetic steel in the jacket (as assumed by Winklhofer et al. [2]) but by the core metals and large differences in their atomic numbers (Z). Each bullet made of copper and zinc (low Z metals) clearly differed from each bullet made of lead (a high Z metal) independent of the metallic components in the jackets. The ferromagnetic lead bullets with steel jackets did not differ from the nonferromagnetic lead bullets with copper/zinc jackets. Consequently, the double number of high Z lead bullets in our ferromagnetic group led to overall low DEIs compared to the nonferromagnetic group.

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Winklhofer et al. [2] selected fourteen lead bullets (with copper/zinc jackets) but only four solid copper/zinc bullets for their nonferromagnetic group. Their ferromagnetic group, in turn, consisted of only one lead bullet (with a steel jacket) but eight bullets made of low Z metals such as copper, zinc, nickel or iron (of which, two bullets contained small amounts of lead in their alloy). Consequently, their nonferromagnetic group consisted of a large number of high Z lead bullets, which led to overall low DEIs compared to the ferromagnetic group.

Unfortunately, the metallic compositions of the bullets selected by Diallo et al. [1] were not analyzed, and only their ferromagnetic properties were tested. According to our aforementioned results [BLINDED], it is highly probable that the ferromagnetic group consisted mainly of bullets composed of high Z metals yielding overall low DEIs, while the nonferromagnetic group consisted mainly of bullets composed of low Z metals leading to overall high DEIs. The division into groups based on ferromagnetic properties regardless of individual metallic components explains the contradiction in the results from Diallo et al. [1] compared to Winklhofer et al. [2].

The differentiation of bullets with ferromagnetic steel jackets from those without by means of the DEI may become viable for magnetic resonance imaging (MRI) safety with further technical developments of the detector arrays. Apart from MRI safety, the DEI-based approach for the differentiation of bullets with regard to their individual metallic components is of interest for forensic purposes. The classification of the metallic components on CT can support the rapid and noninvasive identification of a lodged bullet. A DEI-based classification can be of particular value in the case of deformed or fragmented bullets since a visual assessment would be impeded or infeasible. Further research on this topic is needed to expand the new imaging horizon in forensic pathology.

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